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Deer and Elk Forage Production in Arizona Mixed Conifer Forests

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Mean forage production levels were closely associated with overstory basal area (BA), diminishing rapidly with increasing stand densities. Overstory-understory relationships were generally best described by log or log-log regression equations. Estimated total deer and elk forage on unlogged sites in mid-August is 82 pounds per acre (ovendry weight) at BA 50, versus 4 pounds per acre at BA 400. Expected forage production at BA 0 and 200 would vary from 118 to 5 pounds per acre, respectively, on a 2-year-old thinned site, compared with 448 to 16 pounds per acre on a 4-year-old thinned site. Eight and 16-year-old clearcuts produced 255 and 649 pounds per acre of potential forage, respectively. Forage benefits derived from clearcutting may be long-lived because of slow natural or artificial regeneration.

Keywords: Deer (*Odocoileus hemionus*, *O. virginianus*), elk (*Cervus elaphus*), forage production, mixed conifer forest

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Management Implications

The National Forest Management Act requires National Forests to maintain minimum viable populations of all native wildlife species. Viable populations are a function of the quantity and quality of food and cover. Forage in the form of grass, forbs, and browse has been shown to be related to overstory characteristics and probably contributes more than other factors to the reproduction and maintenance of wild ungulate populations. Information that allows managers to predict understory production by different levels of basal area and treatment categories greatly facilitates the development of habitat capability coefficients. These coefficients are needed to meet the planning requirements of the National Forest Management Act. The regression equations we present for graminoids, forbs, and woody plants can be used as one part of a habitat capability coefficient for the mixed conifer forests of the Southwest.

Introduction

Inadequate nutrition has been suggested as a possible cause for relatively low fawn recruitment associated with declines in southwestern deer populations since the late 1950's (Schneegas and Bumstead 1977, Short 1979). Evidence suggests that quality and quantity of forage produced on summer range can directly influence productivity of deer herds in the West (Julander et al. 1961; Russo 1964; Hungerford 1970; Pederson and Harper 1978).

Together with associated grasslands and wet meadows, Arizona mixed conifer forests provide important summer range for mule deer (*Odocoileus hemionus*), whitetailed deer (*O. virginianus*), and elk (*Cervus elaphus*). Along with associated quaking aspen (*Populus tremuloides*) stands, Arizona's mixed conifer forests comprise 0.4% of the State's total area, but produce more than 6% of its water. More intensive management of these stands is likely because of increasing demands for water and other resources. The effects of this management on deer and elk forage supplies are unknown.

The objective of this study was to develop empirical regression equations to describe forest overstory-understory relationships in Arizona mixed conifer forests to predict potential deer and elk forage. Specifically, this paper reports findings on deer and elk forage production on unlogged, thinned, and clearcut sites, in the White Mountains of Arizona.

Study Areas

Southwestern mixed conifer forests occupy approximately 2.5 million acres in Arizona, New Mexico, and the San Juan Basin of southwestern Colorado (Jones 1974). In Arizona, this type is represented by about 300,000 acres of predominantly uncut, mixed-age stands composed of various combinations of Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), southwestern white pine (*P. strobiformis*), white fir (*Abies concolor*), corkbark fir (*A. lasiocarpa* var. *arizonica*), Engelmann spruce (*Picea engelmannii*), blue spruce (*P. pungens*), and quaking aspen (Embry and Gottfried 1971).

Data were obtained from seven mixed conifer sites on the Apache-Sitgreaves National Forest, Greenlee County, White Mountains, Arizona: North Thomas Creek, South Thomas Creek, West Willow Creek, East Willow Creek, Hannagan Creek, Bear Wallow, and Burro Creek. Data from the first three areas were combined and used to characterize unlogged, old-growth stands. Hannagan Creek and East Willow Creek were used to characterize 2- and 4-year-old thinned stands, respectively. Bear Wallow and Burro Mountain were sampled as 8- and 16-year-old clearcut sites, respectively.

Study area characteristics are summarized in table 1. Distribution of sampling points by aspect is shown because overstory and understory composition are often correlated with aspect (Thill 1981). East Willow Creek was thinned in 1972; sites sampled on Hannagan Creek were thinned in 1974. Logging on Burro Mountain and Bear Wallow was completed in 1959 and 1967, respectively. Logging slash on both clearcuts had been partially removed by broadcast burning. Destruction of advanced regeneration during logging and slash disposal, as well as subsequent regeneration failure, resulted in poor tree stocking on both clearcuts. The few small clumps of older regeneration which were present on these two sites were not sampled. Sampling points on both clearcuts predominantly faced south and southwest.

Annual precipitation at Thomas Creek from 1969 through 1974 averaged 27.0 inches; rainfall in 1975 and 1976 (the years of study) totaled 33.7 and 27.2 inches, respectively. May and June are the driest months, but summer thunderstorms from July through mid-September

Table 1.—Characteristics of mixed conifer sites sampled in the White Mountains of Arizona. Except for sample sizes by aspect, values are means with ranges in parentheses

Characteristic	Study area				
	Unlogged sites	Hannagan Creek	East Willow Creek	Bear Wallow	Burro Mountain
Basal area (ft^2/ac)	189 (50-450)	107 (0-275)	72 (0-300)	0	0
% Aspen	11.2 (0-100)	14.6 (0-100)	29.3 (0-100)		
% Spruce	12.1 (0-100)	14.1 (0-100)	14.6 (0-100)		
% Fir	20.4 (0-100)	9.3 (0-100)	7.5 (0-100)		
% Pine or Douglas-fir	56.6 (0-100)	59.3 (0-100)	23.2 (0-100)		
Elevation	8,874 (7,900-9,400)	8,687 (8,425-9,050)	9,080 (8,900-9,300)	8,800 (8,725-8,875)	9,550 (9,450-9,625)
Slope gradient	24.1 (0-60)	6.6 (0-25)	20.7 (0-40)	20.4 (0-45)	13.6 (0-30)
No. plots sampled by aspect: Total	379	75	142	54	73
North	46	5	17	-	-
Northeast	26	6	18	-	-
Northwest	49	-	11	-	-
South	33	12	12	20	38
Southeast	82	17	35	6	5
Southwest	39	4	-	28	30
East	80	10	34	-	-
West	24	3	15	-	-
Level	-	18	-	-	-

generally produce rain on 50% or more of the days. Summer nights are cool, and a few nights of below freezing temperatures often occur during May and June. Snow cover generally extends from November into April.

Study sites were confined to soils developed from basic basalt under cool, humid conditions. Sponseller was the predominant soil series (Leven and Stender 1967). These are moderately deep and deep, brownish-colored, noncalcareous, well-drained soils of gently-sloping high-elevation plateaus and steep mountains.

Field Methods

Current-year production of browse (leaves and stems 3/16-inch or less in diameter of all woody species except conifers) to a height of 5 feet was determined on 1/100-acre circular plots; herbage was measured on 9.6-square-foot circular plots. Data were collected at fixed intervals along randomly located transects oriented perpendicular to major drainages. Understory production estimates were determined using weight-estimate procedures (Blair 1959). Actual weights were determined at approximately one-seventh of the sampling points. Production was determined for each species encountered so that data could be partitioned into components having potential forage value for deer or elk. A minimum of 10 estimates and actual weights were obtained for each forage species. Average moisture content was determined for each species and was used to adjust data to an ovendry (122° F) basis. Overstory conditions at each plot were characterized by basal area estimates (square feet per acre) derived from point-sampling, utilizing a 25 basal area factor wedge prism. Forested sites were sampled in 1976, clearcuts in 1975. Understory data were collected during August 13-26 in both years.

To quantify deer and elk forage production responses to forest management practices, all plants were rated as either valuable or not valuable as potential forage for deer and/or elk (table 2). Limited forage preference data dealing specifically with southwestern mixed conifer sites necessitated considerable reliance on food-habits literature from other western states. Ratings were further substantiated by on-site observations and data collected by Wallmo and McCulloch (1963) and Hungerford (1970). Ratings for mule deer were based on work by Hungerford (1970), Kufeld et al. (1973), Neff (1974), and Urness et al. (1975). The source used for elk was Kufeld (1973). Species rated as valuable generally correspond to Kufeld's (1973) "highly valuable" or "valuable" categories. As such, these plants would be moderately to

highly preferred and would be expected to make up a moderate to major portion of the animals' diets, if encountered. Species rated in these references as valuable only during spring (March through May) or winter (December through February) were not classified as potential forages, because deer and elk use of the study area is normally restricted to a period from May to early October.

Table 2.—Woody and herbaceous plant species growing on logged and unlogged mixed conifer sites in Arizona which were rated as potentially valuable forage species for mule deer and/or elk

Botanical name[1]	Common name	Deer[2]	Elk[2]
Woody Plants			
Acer glabrum Torr.	Rocky Mountain maple	*	*
Amelanchier spp.	serviceberry	*	
Berberis repens Lindl.	creeping mahonia	*	*
Ceanothus fendleri Gray	Fendler ceanothus	*	
Lonicera arizonica Rehd.	Arizona honeysuckle	*	*
Lonicera utahensis Wats.	Utah honeysuckle		*
Pachystima myrsinites (Pursh.) Raf.	myrtle pachistima	*	*
Populus tremuloides Michx.	quaking aspen	*	*
Quercus gambelii Nutt.	Gambel oak	*	*
Ribes pinetorum Greene	orange gooseberry		*
Rosa arizonica Rydb.	Arizona rose		*
Robinia neomexicana Gray	New Mexico locust	*	
Rubus parviflorus Nutt.	western thimbleberry	*	*
Rubus strigosus Michx.	red raspberry	*	
Sambucus spp.	elderberry	*	*
Salix scouleriana Barratt	Scouler willow	*	*
Symphoricarpos oreophilus Gray	mountain snowberry	*	*
Vaccinium myrtillus L.	Rocky Mountain whortleberry		*
Forbs			
Achillea lanulosa Nutt.	western yarrow	*	
Actaea rubra (Ait.) Willd.	red baneberry	*	
Aster foliaceus Lindl.	leafybract aster	*	
Cirsium parryi (Gray) Petrak	thistle		*
Cirsium pulchellum (Greene) Woot. and Standl.	thistle		*
Epilobium angustifolium L.	fireweed	*	*
Erigeron flagellaris Gray	trailing fleabane	*	
Geranium caespitosum James	purple geranium		*
Geranium richardsonii Fisch. and Trautv.	Richardson geranium	*	*
Hieracium fendleri Schultz Bip.	hawkweed	*	
Houstonia wrightii Gray	Wrights bluets	*	
Ligusticum porteri Coult. and Rose	Porter ligusticum	*	
Lupinus argenteus Pursh.	silvery lupine	*	*
Osmorhiza depauperata Phil.	bluntseed sweetroot	*	
Phacelia magellanica (Lam.) Coville	phacelia	*	*
Polygonum aviculare L.	prostrate knotweed	*	*
Potentilla hippiana Lehm.	horse cinquefoil		*
Potentilla thurberi Gray	Thurber cinquefoil		*
Pseudocymopterus montanus (Gray) Coult. and Rose	pseudocymopterus	*	
Senecio bigelovii Gray	Bigelow groundsel		*
Silene scouleri	Scouler silene	*	
Smilacina racemosa (L.) Desf.	feather solomonplume	*	*
Swertia radiata (Kellogg) Kuntze	deer ears	*	
Taraxacum officinale Weber	common dandelion	*	*
Thalictrum fendleri Gray	Fendler meadow-rue	*	
Trifolium pinetorum Greene	clover	*	
Vicia americana Muhl.	American vetch	*	*
Vicia pulchella H.B.K.	sweetclover vetch	*	*
Viquiera multiflora (Nutt.) Blake	showy goldeneye	*	

Table 2.—continued

Table 2.—Woody and herbaceous plant species growing on logged and unlogged mixed conifer sites in Arizona which were rated as potentially valuable forage species for mule deer and/or elk—(Continued)

Botanical name[1]	Common name	Deer[2]	Elk[2]
Graminoids			
Agrostis alba L.	redtop		*
Agropyron desertorum (Fisch). Schult.	crested wheatgrass	*	
Agropyron smithii Rydb.	bluestem wheatgrass		*
Agropyron subsecundum (Link) Hitchc.	bearded wheatgrass		*
Bromus inermis Leyss.	smooth brome	*	*
Dactylis glomerata L.	orchardgrass	*	*
Festuca arizonica Vasey	Arizona fescue	*	
Koeleria cristata Pers.	prairie junegrass	*	*
Muhlenbergia montana (Nutt). Hitchc.	mountain muhly	*	
Muhlenbergia virescens (H.B.K.) Kunth	screwleaf muhly		*
Panicum bulbosum H.B.K.	bulb panicum		*
Phleum pratense L.	timothy		*
Poa fendleriana (Steud.) Vasey	mutton bluegrass	*	*
Poa pratensis L.	Kentucky bluegrass	*	*
Sitanion hystrix (Nutt.) J. G. Sm.	bottle brush	*	

[1]*Scientific and common names follow Nickerson, Brink, and Feddema (1976); they follow Kearney and Peebles (1960) and Kelsey and Dayton (1942) if not listed by Nickerson et al.*
[2]*Asterisks denote species of potential forage value to deer or elk during summer or fall.*

Analytic Methods

Weighted regression procedures were used to predict understory (forb, graminoid, and woody plant) production and production of deer and elk forage (herbage, browse, and total forage) using basal area as the independent variable. Total basal area was regressed with mean production values associated with 25 square feet basal area increment. Where observations are means, as is the case here, the inverse of the variance of the mean is an appropriate weighting factor, particularly where sample sizes vary considerably for each level of the independent variable (Steel and Torrie 1960). Thus, the factor used to weight each production value was:

$$w_i = n_i/s_i^2$$

where n_i and s_i^2 are the sample size and variance, respectively, associated with each mean.

Of the following models which were screened, only the one with the highest r-value is presented: $Y = f(X)$, $Y = f(LgX)$, $LgY = (X)$, $LgY = f(LgX)$, $Y = f(1/X)$; Lg denotes a common log to base 10 transformation. One was added to all values prior to logarithmic transformation.

Procedures outlined by Meyer (1942) and exemplified by Clary and Ffolliott (1966) were used to test for differences in production of understory components between weighted regression curves developed for unlogged and thinned stands. The jackknife procedure was used to estimate a variance of the estimate for each basal value used in the comparison tests (Mosteller and Tukey 1977). Comparisons between the unlogged treatment and each of the thinned sites were made from basal area (BA) 50 (the lowest BA sampled on the unlogged sites) to 225 (the highest BA on Hannagan Creek and Willow Creek for which at least two plots were inventoried). East Willow Creek and Hannagan Creek were compared from BA 0 through BA 225. Production differences were tested at 25-square-foot increments (i.e., BA 0, 25, 50, . . .). All tests of significance were at the 0.05 level.

Results

Unlogged Sites

Weighted regressions of means of understory production components with total basal area yielded an average r^2 of 0.71 for those relationships having significant regression coefficients; r^2 values ranged from 0.18 for forbs (Y2) to 0.86 for total understory production (Y4) (table 3). Log and log-log functions produced highest r^2 values for all understory components except forbs. The linear model yielded the highest r^2 for forbs. None of the models tested yielded significant ($P > 0.05$) regression coefficients for deer and elk browse components (i.e., Y6, Y9, and Y12).

Graminoids (Y1) were a minor understory component except in fairly open stands. At BA 100 or higher, less than 35 pounds per acre of graminoids would be expected, as compared to about 125 pounds per acre at BA 50. Forbs (Y2) were the most important understory component for all basal area levels higher than about 85, but were out-produced by graminoids below this BA level.

The regression line for woody plants production (Y3) was nearly linear, with production increasing only slightly with decreasing stand density; at the lowest basal area sampled (BA 50), less than 15 pounds per acre would be expected.

Predicted levels of total understory production and various deer and elk forage components at selected basal area levels are presented in table 4. Predicted total understory production (Y4) would range from a low of 35 pounds per acre at BA 400 to a high of about 140 pounds per acre at BA 50. As indicated in this table, not only does total understory production rapidly decline with increasing stand density, but the percentage of this total having potential value to deer and elk also rapidly declines with increasing density. For example, potential elk forage (Y10) as a percent of total understory production (Y4) decreases from 39% at BA 50 to 11% at BA 400.

Unlogged stands produced somewhat greater quantities of elk forage than deer forage at lower stand densities, but approximately equal amounts for both animals at higher stand densities (table 4). At BA 50, 28%, 39%, and 58% of total understory production would consist of deer, elk, and deer or elk forage, respectively. Potential deer forage (Y7) would consist of about one-third herbage (Y5) and two-thirds browse (Y6) throughout the range of stand densities sampled. Elk forage (Y10) would consist primarily of herbage (Y8) at lower basal area levels, and equal amounts of herbage and browse at BA 400. Total production of species having potential value to either deer or elk (Y13) would comprise 58% of total understory production at BA 50, compared with 11% at BA 400.

Few forage species were encountered on plots with the highest basal area (table 5). For example, 94% of the total deer and elk forage (Y13) for plots with BA 375 through 400 was produced by 4 species, while 11 species produced 97% at BA 50 to 75. Although grasses were a minor understory component (except under lower stand densities), they were the principal forages under low, medium, and high basal area levels (table 5).

Thinned Sites

For the 2-year-old thinning on Hannagan Creek, logarithmic function produced highest r^2 values when means of understory components were regressed with BA (table 3). Value of r^2 ranged from 0.51 for deer herb-

Table 3.—Weighted regression equations of mean understory production components with basal area (X) for unlogged and thinned mixed conifer sites in the White Mountains of Arizona

Stand condition	Vegetation group[1]	Regression equation	SEE	r^2
Unlogged	Graminoids	Lg(Y1) = 5.471 - 1.974 Lg(X)	.060	.81
	Forbs	Y2 = 47.50 - 0.039 (X)	1.05	.18
	Woody plants	Y3 = 36.64 - 13.91 Lg(X)	.840	.84
	Total understory prod.	Lg(Y4) = 3.299 - .6693 Lg(X)	.005	.86
	Herbage for deer	Lg(Y5) = 2.797 - .9774 Lg(X)	.105	.58
	Total deer forage	Lg(Y7) = 3.643 - 1.189 Lg(X)	.040	.83
	Herbage for elk	Lg(Y8) = 3.995 - 1.348 Lg(X)	.045	.72
	Total elk forage	Lg(Y10) = 3.764 - 1.178 Lg(X)	.030	.77
	Deer and elk herbage	Lg(Y11) = 4.120 - 1.396 Lg(X)	.045	.71
	Total deer and elk forage	Lg(Y13) = 4.259 - 1.370 Lg(X)	.030	.82
Thinned 2 years prior	Graminoids	Y1 = 55.55 - 23.63 Lg(X)	2.19	.55
	Forbs	Y2 = 331.1 - 136.3 Lg(X)	1.39	.92
	Woody plants	Lg(Y3) = 1.163 - .0034 (X)	.080	.86
	Total understory prod.	Y4 = 407.2 - 166.4 Lg(X)	1.68	.99
	Herbage for deer	Y5 = 51.00 - 22.66 Lg(X)	3.65	.51
	Total deer forage	Y7 = 80.39 - 33.41 Lg(X)	2.78	.72
	Herbage for elk	Y8 = 77.57 - 33.15 Lg(X)	2.68	.68
	Total elk forage	Y10 = 107.1 - 44.20 Lg(X)	2.19	.77
	Deer and elk herbage	Y11 = 90.64 - 38.85 Lg(X)	3.29	.65
	Total deer and elk forage	Y13 = 118.0 - 48.98 Lg(X)	2.58	.75
Thinned 4 years prior	Graminoids	Y1 = 296.6 - 122.6 Lg(X)	3.35	.39
	Forbs	Y2 = 247.6 - 104.7 Lg(X)	2.83	.64
	Woody plants	Lg(Y3) = 2.020 - .5962 Lg(X)	.070	.50
	Total understory prod.	Y4 = 663.6 - 279.1 Lg(X)	2.55	.82
	Herbage for deer	Y5 = 211.9 - 89.50 Lg(X)	2.24	.68
	Total deer forage	Y7 = 373.6 - 156.0 Lg(X)	1.70	.89
	Herbage for elk	Lg(Y8) = 2.181 - .0093 (X)	.064	.99
	Total elk forage	Y10 = 397.2 - 166.8 Lg(X)	2.36	.83
	Deer and elk herbage	Y11 = 234.8 - 99.28 Lg(X)	2.60	.62
	Total deer and elk forage	Y13 = 448.2 - 187.8 Lg(X)	2.10	.85

[1] *Regression coefficients for deer and elk browse components (i.e., Y6, Y9, and Y12) were not significant at the 0.05 level.*

Table 4.—Predicted amounts (pounds per acre) of total understory production and various deer and elk forage components at selected basal area levels for unlogged mixed conifer sites[1]

Vegetation group	Basal area 50	100	200	400
Total production Y4	142	90	56	35
Deer herbage Y5	12 (8)[2]	6 (7)	3 (5)	1 (3)
Deer browse Y6	28 (20)	11 (12)	4 (7)	2 (6)
Total deer forage Y7	40 (28)	17 (19)	7 (13)	3 (9)
Elk herbage Y8	48 (34)	19 (21)	7 (13)	2 (6)
Elk browse Y9	8 (6)	5 (6)	3 (5)	2 (6)
Total elk forage Y10	56 (39)	24 (27)	10 (18)	4 (11)
Deer or elk herbage Y11	53 (37)	20 (22)	7 (13)	2 (6)
Deer or elk browse Y12	29 (20)	12 (13)	5 (9)	2 (6)
Total deer or elk forage Y13	82 (58)	32 (36)	12 (21)	4 (11)

[1]*Values for herbage and total forage categories were obtained from weighted regression equations presented in Table 3; browse values were obtained by subtraction.*
[2]*Values in parentheses indicate the percent that the preceding value is of total understory production (Y4). All values rounded to nearest whole number.*

Table 5.—Principal deer and elk forage species present at low, medium, and high basal area classes on unlogged mixed conifer sites[1]

Basal area class (ft²/ac) 50-75 (n = 33)		225 (n = 31)		375-400 (n = 10)	
Muhlenbergia virescens	(30)	*Muhlenbergia virescens*	(28)	*Bromus inermis*	(41)
Muhlenbergia montana	(20)	*Lupinus argenteus*	(15)	*Geranium richardsonii*	(24)
Robinia neomexicana	(11)	*Pachystima myrsinites*	(11)	*Populus tremuloides*	(23)
Bromus inermis	(8)	*Bromus inermis*	(7)	*Pseudocymopterus montanus*	(6)
Quercus gambelii	(7)	*Quercus gambelii*	(6)		
Vicia americana	(6)	*Populus tremuloides*	(5)		
Pachystima myrsinites	(5)	*Koeleria cristata*	(4)		
Geranium richardsonii	(3)	*Robinia neomexicana*	(4)		
Lupinus argenteus	(3)	*Senecio bigelovii*	(4)		
Populus tremuloides	(2)	*Geranium richardsonii*	(3)		
Sitanion hystrix	(2)	*Thalictrum fendleri*	(3)		
		Achillea lanulosa	(3)		

[1]*Only species making up >0.5 percent of total understory production (Y4) within the indicated basal area classes are listed. Values in parentheses indicate percent of total deer and elk forage (Y13), rounded to nearest whole number.*

age (Y5) to 0.99 for total understory production (Y4), and averaged 0.74 for all forage components on Hannagan Creek. None of five models tested provided significant regression coefficients for deer and elk browse variables Y6, Y9, and Y12. Predicted total understory production (Y4) would range from 15 pounds per acre at BA 225 to 407 pounds per acre at BA 0. Forbs were the dominant understory component at all basal area levels. Maximum browse production was 14 pounds per acre at BA 0. Graminoids were a minor understory component except at low stand densities.

Predicted levels of total understory production (Y4) and deer and elk forage at selected BA levels are presented in table 6. Unlike unlogged stands (but like the 4-year-old East Willow Creek thinning), that portion of total understory production which consisted of deer (Y7) and elk (Y10) forage remained fairly constant with increasing stand density. As with East Willow Creek 4 years after logging, similar 2-year-old thinned stands would be expected to produce approximately equal amounts of deer (Y7) and elk (Y10) forage throughout the range of basal area sampled. Total forage potentially useful to deer or elk would be about 29% of total understory production (Y4) at BA 0 versus 21% at BA 200.

For the 4-year-old thinning on East Willow Creek, logarithmic functions produced highest r^2 values for all significant relationships when means of understory production components were regressed with basal area. Values of r^2 ranged from 0.39 for graminoids (Y1) to 0.99

for elk herbage (Y8), and averaged 0.72. None of the models produced significant regression coefficients for deer and elk browse components.

Graminoid production (Y1) would vary from 8 pounds per acre at BA 225 to 300 pounds per acre at BA 0. Like unlogged stands, browse production was inversely related to basal area, and increased only slightly with decreasing stand density to a maximum of 104 pounds per acre at BA 0. Predicted total understory production (Y4) would range from a low of 6 pounds per acre at BA 225 to a high of 663 pounds per acre at BA 0.

In contrast to unlogged sites, deer and elk forage (Y7, Y10, and Y13) as a percent of total production (Y4), remained fairly constant with increasing basal area (table 6). Thus, although less vegetation is present at higher basal area levels, more of what is present is potentially useful deer and elk forage. Data in table 6 suggest that similar 4-year-old thinned stands would produce somewhat more deer herbage (Y5) than elk herbage (Y8), but approximately equal amounts of total deer (Y7) and elk (Y10) forage at similar basal levels throughout the range of stand densities sampled.

As with unlogged sites, fewer forage species were encountered on higher than lower basal area plots on both thinned sites (tables 7 and 8). Grasses dominated deer and elk forage production at the lowest basal area classes on both thinned sites, but quaking aspen dominated at intermediate and high basal area levels (tables 7 and 8).

Comparisons Among Sites

Basal area levels at which significant differences ($P < 0.05$) were detected in predicted yields of various understory vegetation groups, when weighted regression curves developed for the unlogged, and the 2- and 4-year-old sites were compared, are summarized in table 9. The 4-year-old thinning produced significantly greater amounts of forbs (Y2), total understory production (Y4), and deer and elk forage (Y7, Y10, and Y13) than unlogged sites under certain basal area levels. Forb production (Y2) at BA 50 was greater on the 2-year-old thinning than on unlogged sites, but unlogged stands produced more total deer and elk forage (Y13) under low basal area conditions. Production of 8 of the 10 understory components was significantly greater on the 4- than the 2-year-old thinning, especially under lower stand densities. A graphic comparison of differences in total understory production and total deer and elk forage for unlogged and thinned stands is shown in figure 1.

Clearcut Sites

Total herbage and browse production on the 16-year-old clearcut (Burro Mountain) was nearly twice that of the 8-year-old clearcut (Bear Wallow) (table 10). Forbs were the dominant vegetative component on the younger clearcut, but graminoids and forbs were equally impor-

Table 6.—Predicted amounts (pounds per acre) of total understory production and various deer and elk forage components at selected basal area levels for two mixed conifer sites thinned 2 (Hannagan Creek) and 4 years (East Willow Creek) earlier[1]

Site	Vegetation group	Basal area (ft^2/ac) 0	50	100	200
Hannagan Creek	Total production Y4	407	123	74	24
	Deer herbage Y5	51 (13)[2]	12 (10)	6 (8)	0
	Deer browse Y6	29 (7)	11 (9)	7 (9)	3 (13)
	Total deer forage Y7	80 (20)	23 (19)	13 (18)	3 (13)
	Elk herbage Y8	78 (19)	21 (17)	11 (15)	1 (4)
	Elk browse Y9	29 (7)	11 (9)	8 (11)	4 (17)
	Total elk forage Y10	107 (26)	32 (26)	19 (26)	5 (21)
	Deer or elk herbage Y11	91 (22)	24 (20)	13 (18)	1 (4)
	Deer or elk browse Y12	27 (7)	10 (8)	7 (9)	4 (17)
	Total deer or elk forage Y13	118 (29)	34 (28)	20 (27)	5 (21)
East Willow Creek	Total production Y4	664	187	104	21
	Deer herbage Y5	212 (32)	59 (32)	33 (32)	6 (29)
	Deer browse Y6	162 (24)	48 (26)	28 (27)	8 (38)
	Total deer forage Y7	374 (56)	107 (57)	61 (59)	14 (67)
	Elk herbage Y8	151 (23)	51 (27)	17 (16)	1 (5)
	Elk browse Y9	246 (37)	61 (33)	46 (44)	12 (57)
	Total elk forage Y10	397 (60)	112 (60)	63 (60)	13 (62)
	Deer or elk herbage Y11	235 (35)	65 (35)	36 (35)	6 (29)
	Deer or elk browse Y12	213 (32)	63 (34)	36 (35)	10 (48)
	Total deer or elk forage Y13	448 (67)	128 (68)	72 (69)	16 (76)

[1] *Values for herbage and total forage categories were obtained from weighted regression equations presented in Table 3; browse values were obtained by subtraction.*

[2] *Values in parentheses indicate the percent that the preceding value is of total understory production (Y4) for respective site. All values rounded to nearest whole number.*

Table 7.—Principal deer and elk forage species present at low, medium, and high basal area classes on Hannagan Creek 2 years after logging[1]

Basal area class (ft²/ac)					
0-25 (n = 10)		100-125 (n = 22)		200-225 (n = 6)	
Sitanion hystrix	(41)	*Populus tremuloides*	(50)	*Populus tremuloides*	(74)
Koeleria cristata	(25)	*Koeleria cristata*	(24)	*Muhlenbergia virescens*	(18)
Phacelia magellanica	(12)	*Geranium richardsonii*	(9)	*Bromus inermis*	(6)
Populus tremuloides	(10)	*Bromus inermis*	(7)		
Bromus inermis	(6)	*Phacelia magellanica*	(6)		
Robinia neomexicana	(3)				
Geranium richardsonii	(2)				
Achillea lanulosa	(2)				

[1]*Only species making up >0.5 percent of total understory production (Y4) within the indicated basal area classes are listed. Values in parentheses indicate percent of total deer and elk forage (Y13), rounded to nearest whole number.*

Table 8.—Principal deer and elk forage species present at low, medium, and high basal area classes on East Willow Creek 4 years after logging[1]

Basal area class (ft²/ac)					
0-25 (n = 62)		125 (n = 8)		225-250 (n = 7)	
Bromus inermis	(39)	*Populus tremuloides*	(68)	*Populus tremuloides*	(56)
Phacelia magellanica	(15)	*Bromus inermis*	(16)	*Bromus inermis*	(20)
Populus tremuloides	(13)	*Geranium richardsonii*	(4)	*Vaccinium myrtillus*	(20)
Sitanion hystrix	(10)	*Phacelia magellanica*	(4)	*Erigeron flagellaris*	(3)
Geranium richardsonii	(5)	*Erigeron flagellaris*	(3)	*Pseudocymopterus montanus*	(1)
Koeleria cristata	(3)	*Lupinus argenteus*	(2)	*Rubus parviflorus*	(1)
Lupinus argenteus	(3)	*Vaccinium myrtillus*	(1)		
Achillea lanulosa	(3)	*Pseudocymopterus montanus*	(1)		
Erigeron flagellaris	(2)				
Vicia americana	(2)				
Dactylis glomerata	(1)				
Ribes pinetorum	(1)				
Cirsium spp.	(1)				
Phleum pratense	(1)				

[1]*Only species making up >0.5 percent of total understory production (Y4) within the indicated basal area classes are listed. Values in parentheses indicate percent of total deer and elk forage (Y13), rounded to nearest whole number.*

tant on Burro Mountain. Sedges (*Carex* spp.) comprised 18.3% and 25.9% of the graminoid production on Bear Wallow and Burro Mountain, respectively. Browse production was negligible on both clearcuts. In addition to higher total production, Burro Mountain also produced a greater proportion (56.1% versus 33.9%) of forage having potential forage value to deer and elk (table 10). Production of potential elk forage was somewhat higher than deer forage on both clearcuts. The contribution of principal deer and elk forage species to total production is summarized in table 11.

Expected understory production for plots with less than 25 square feet per acre of basal area for Hannagan Creek and East Willow Creek (from equations in table 3) and actual production values from Bear Wallow and Burro Mountain are plotted against time since logging (fig. 2). Judging from these limited data, the following general trends are suggested:

1. Forb production may have already peaked by age 16.
2. Browse production peaked shortly after logging.
3. Graminoid production may still increase for several years beyond age 16.
4. Peak total production, consequently, may be several years into the future.

Discussion

With regard to successional patterns on clearcuts, Basile and Jensen (1971) observed similar forb and

Table 9.—Basal area levels at which significant differences ($P<0.05$) were detected in predicted yields of understory vegetation groups when weighted regression curves developed for the three timbered treatments were compared at selected basal area levels

		Treatments compared and basal area ranges tested[1]		
Vegetation group[2]		UMC vs EWC BA 50-225	UMC vs HC BA 50-225	EWC vs HC BA 0-225
Graminoids	Y1			0[b]
Forbs	Y2	50-75[b]	50[c]	
Woody plants	Y3			0[b]
Total production	Y4	50-75[b]		0-50[b]
Deer herbage	Y5			
Total deer forage	Y7	50-150[b]		0-75[b]
Elk herbage	Y8			0[b]
Total elk forage	Y10	50-175[b]		0-175[b]
Deer or elk herbage	Y11			0[b]
Total deer or elk forage	Y13	50-175[b]	50-75[a]	0-175[b]

[1] *Where differences are significant, the treatment with the higher production in each comparison is indicated by the following superscripts: a = unlogged mixed conifer sites (UMC); b = East Willow Creek (EWC); and c = Hannagan Creek (HC).*

[2] *Weighted regression coefficients for deer and elk browse variables Y6, Y9, and Y12 were not significant.*

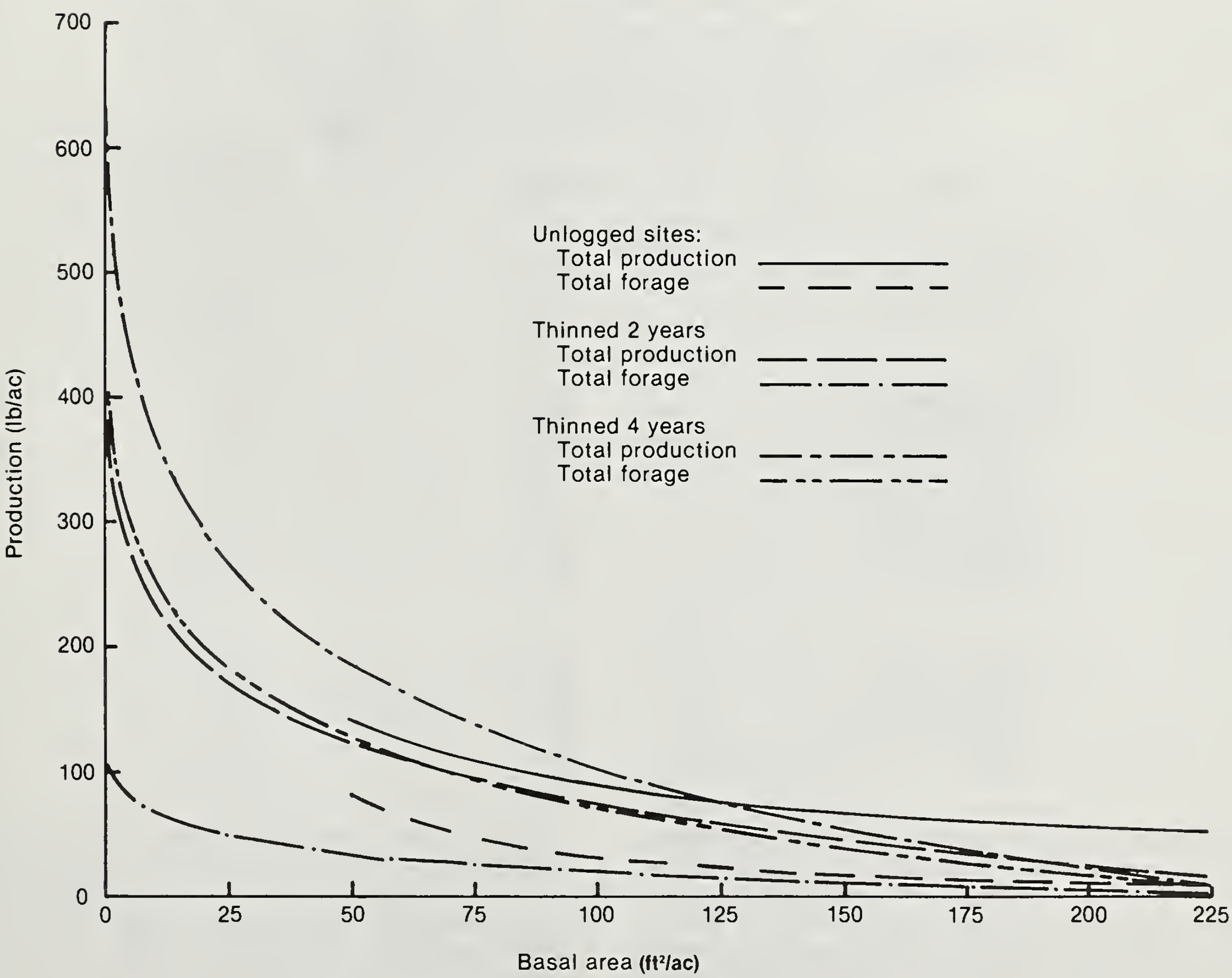

Figure 1.—Comparison of total understory production (Y4) and total deer and elk forage production (Y13) on unlogged and thinned mixed conifer sites, White Mountains, Arizona.

Table 10.—Herbage and browse production on two mixed conifer sites clearcut 8 (Bear Wallow) and 16 years (Burro Mountain) prior to 1975 inventory listed by plant groups and by forage components potentially useful to deer and elk

Vegetation group	Bear Wallow pounds per acre	Bear Wallow %	Burro Mountain pounds per acre	Burro Mountain %
Total production				
Graminoids	183	24.3	533	46.0
Forbs	535	71.1	615	53.1
Woody plants	34	4.5	10	0.9
Total	752	99.9	1158	100.0
Deer forage[1]				
Herbage	151	20.1	371	32.0
Browse	16	2.1	3	0.3
Total	167	22.2	374	32.3
Elk forage				
Herbage	206	27.4	393	33.9
Browse	12	1.6	8	0.7
Total	218	29.0	401	34.6
Deer and elk forage				
Herbage	234	31.1	639	55.2
Browse	21	2.8	10	0.9
Total	255	33.9	649	56.1

[1]*Percentage values from here down are percent of total production values from preceding line.*

Table 11.—Principal deer and/or elk forage species on Bear Wallow and Burro Mountain clearcuts as a percent by weight of total production

Species	Bear Wallow	Burro Mountain
Woody plants		
Ribes pinetorum	1.4	0.7
Rubus strigosus	1.1	0.2
Subtotal	2.5	0.9
Grasses		
Bromus inermis	11.2	7.3
Dactylis glomerata	1.9	0.0
Festuca arizonica	0.0	15.6
Koeleria cristata	0.0	1.4
Muhlenbergia montana	0.0	1.7
Phleum pratense	2.4	0.0
Poa fendleriana	1.2	tr
Sitanion hystrix	1.6	3.0
Subtotal	18.3	29.0
Forbs		
Achillea lanulosa	0.5	3.3
Cirsium parryi	0.0	10.6
Phacelia magellanica	2.2	0.7
Subtotal	2.7	14.6
Total	23.5	44.5

graminoid production trends on clearcut lodgepole pine sites in Montana. They found that production of the dominant forb class peaked at 10 years, while graminoid production peaked at about 2 to 3 years later. Browse was also the least productive class initially, but (unlike here) continually increased and exceeded production of each of the other classes at about 14 years after clearcutting.

In mixed conifer stands, between 7,000 and 9,000 feet elevation, in southern New Mexico, Hanks and Dick-Peddie (1974) found that a dominant forb stage was typically followed by a second stage dominated by Gambel oak (*Quercus gambelii*) and locust (*Robinia neomexicana*) along with several other deciduous shrubs. Moir and Ludwig (1979) also described several mixed conifer habitat types having a more productive

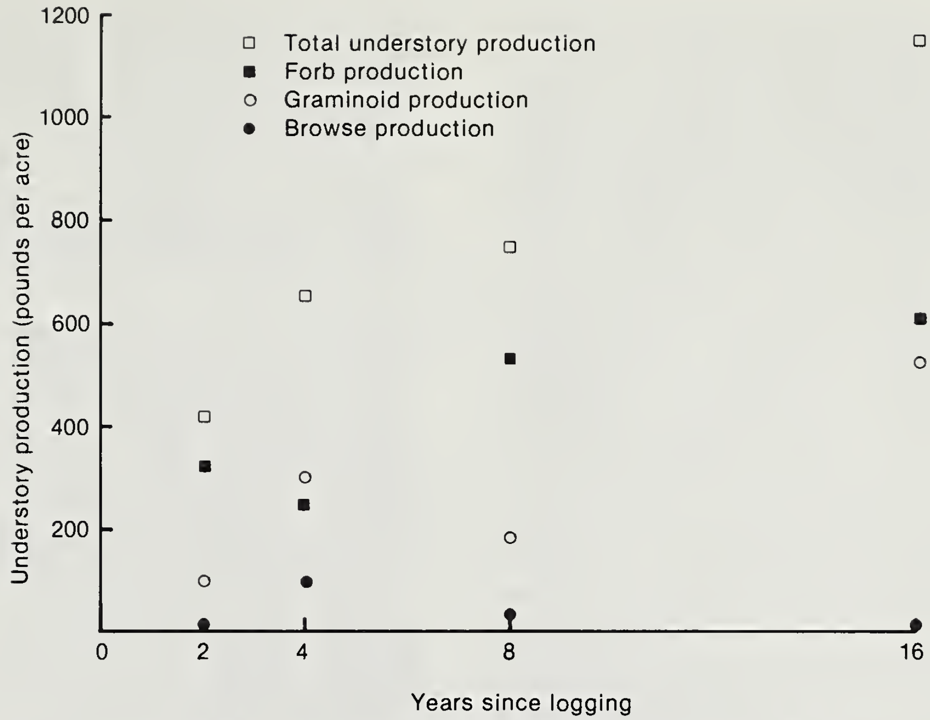

Figure 2.—Trends in understory production for thinned sites with less than 25 ft² of basal area (ages 2 and 4) and for clearcut mixed conifer sites as affected by time.

shrub component than those sampled in this study. In searching for suitable clearcut sites, several sites were observed which had developed relatively dense stands of locust, raspberry (*Rubus* spp.), and gooseberry (*Ribes* spp.). However, except for a few isolated concentrations of Gambel oak and locust (particularly on portions of the South Fork of Thomas Creek), these species were not a major understory component on any of the forested areas sampled. Where Gambel oak and locust were present on unlogged sites, they generally had grown beyond the reach of deer and elk. Given the relative scarcity of these species on unlogged and thinned sampling areas, it was felt that these species probably would not be a major successional component if these areas had been clearcut. Consequently, the two clearcuts which were sampled were selected as being representative of how these particular forest sites might respond to clearcutting.

In addition to the influence of habitat types on occurrence of a dominant shrub stage, extent of site disturbance and inherent soil moisture conditions may also be important. On logged and burned Douglas-fir sites in Oregon, Dyrness (1973) only observed a dominant shrub stage on the more heavily burned, drier sites. However, on more moist, less disturbed sites he suggested that succession would proceed from a mixture of ferns, herbs, and low shrubs directly to trees. Most of the shrub-dominated clearcuts observed in this study appeared to be fairly wet sites having shallow, rocky soils.

Deer and elk also may have had some influence on initial shrub abundance and vigor, at least on Burro Mountain. Jones (1967) indicated that both animals were numerous on this area and caused serious browsing damage to planted ponderosa pine shortly after logging and pine planting.

An invasion of conifers (with or without aspen) initiates the final successional stage on mixed conifer sites. However, substantial natural regeneration often requires 50 to 100 years, especially where dense stands of grasses and forbs develop (Stahelin 1943, Hanks and Dick-Peddie 1974). Given their inherent productivity, long life, and abundance of desirable deer and elk forage, it would appear that mixed conifer clearcuts (at least those on predominantly south and southwest aspects) provide a valuable long-term forage resource for both deer and elk.

Unlogged mixed conifer forests produce little understory even under basal area levels as low as 50 square feet per acre. At BA 189 (the overall mean for unlogged sites), predicted total production of deer and elk forage would be about 13 pounds per acre. At 4 years after thinning, East Willow Creek produced significantly greater amounts of deer and elk forage (Y13) for BA 50 through 175 than unlogged sites. Furthermore, these increases in forage after thinning were accompanied by a gradual increase in deer and elk use as indexed by accumulated pellet groups (Patton 1976). From 1973 through 1975, number of deer and elk pellet groups averaged 1.8 times greater on East Willow Creek than on the adjacent, unlogged, West Willow Creek where their numbers remained constant.

Although their production was not measured, mushrooms were abundant on unlogged sites after summer rains. Many of these mushrooms contribute substantially to late summer diets of mule deer (Hungerford 1970), and their presence is presumed to be at least a

partial cause for considerable use of mature stands during this season (Rasmussen 1941).

Relatively low understory production on the 2-year-old Hannagan Creek thinning is not unusual for recently logged sites, and is often related to degree of site disturbance and method of slash disposal (Reynolds 1962, Regelin and Wallmo 1978). Total production of deer and elk forage was significantly greater on East Willow Creek at 4 years than on Hannagan Creek at 2 years after logging, over most of the basal area range sampled. Seeding recently logged sites with preferred forage species would be one means of accelerating their value to deer and elk. It is not known when forage production will peak on these thinned sites, but herbage production on selectively logged ponderosa pine and mixed conifer sites on the North Kaibab Plateau increased annually from the second to the sixth year after logging, and then declined until, at age 11 to 15, it was comparable to uncut sites (Reynolds 1962). Consequently, the beneficial deer and elk forage response resulting from selective logging may be shorter-lived than that derived from clearcutting.

That significant differences were found between regression curves for unlogged and logged stands suggests the need for developing separate equations for pre- and post-logging conditions. In a comparison of thinned and unthinned ponderosa pine stands, Clary and Ffolliott (1966) found significantly greater understory production in thinned stands for basal area levels of less than 70 square feet per acre. They suggested that these differences could be caused by changes in forest overstory stocking arrangements and/or size class distribution. For example, extensive removal of smaller diameter trees (e.g., precommercial thinning or through natural thinning processes) from a multiple-age stand can result in a relatively high residual basal area and yet, substantial understory production resulting from better light conditions. Physical disturbances caused by logging (e.g., forest floor alterations, reduction in competing shrub or hardwood cover, or a reduction in overstory crown cover due to limb breakage) also may contribute to these differences.

Although clearcuts and the older thinned site produced more potential deer and elk forage than unthinned sites, maximum utilization of this additional forage can only be achieved through judicious integration of forest and wildlife management practices. Forest managers should consider how size, shape, and juxtaposition of cutting units will influence quality and availability of foraging areas, and hiding and thermal cover. Utilization of treated areas also will be influenced by availability of water, the manner in which logging slash is treated, and the location and design of roads as they influence disturbance from humans.

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